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Title: Phloem transport and drought

Author(s): Sevanto, Sanna A.

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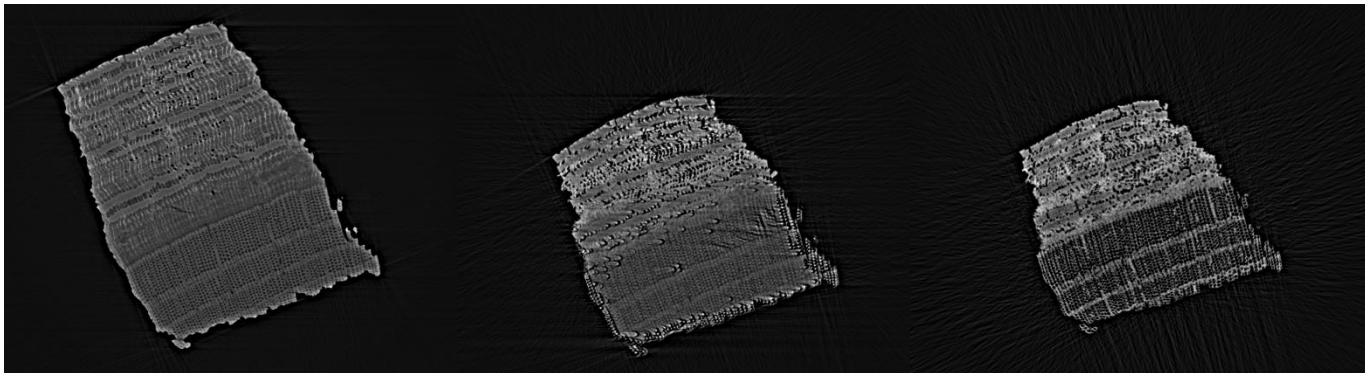


# Phloem transport and drought

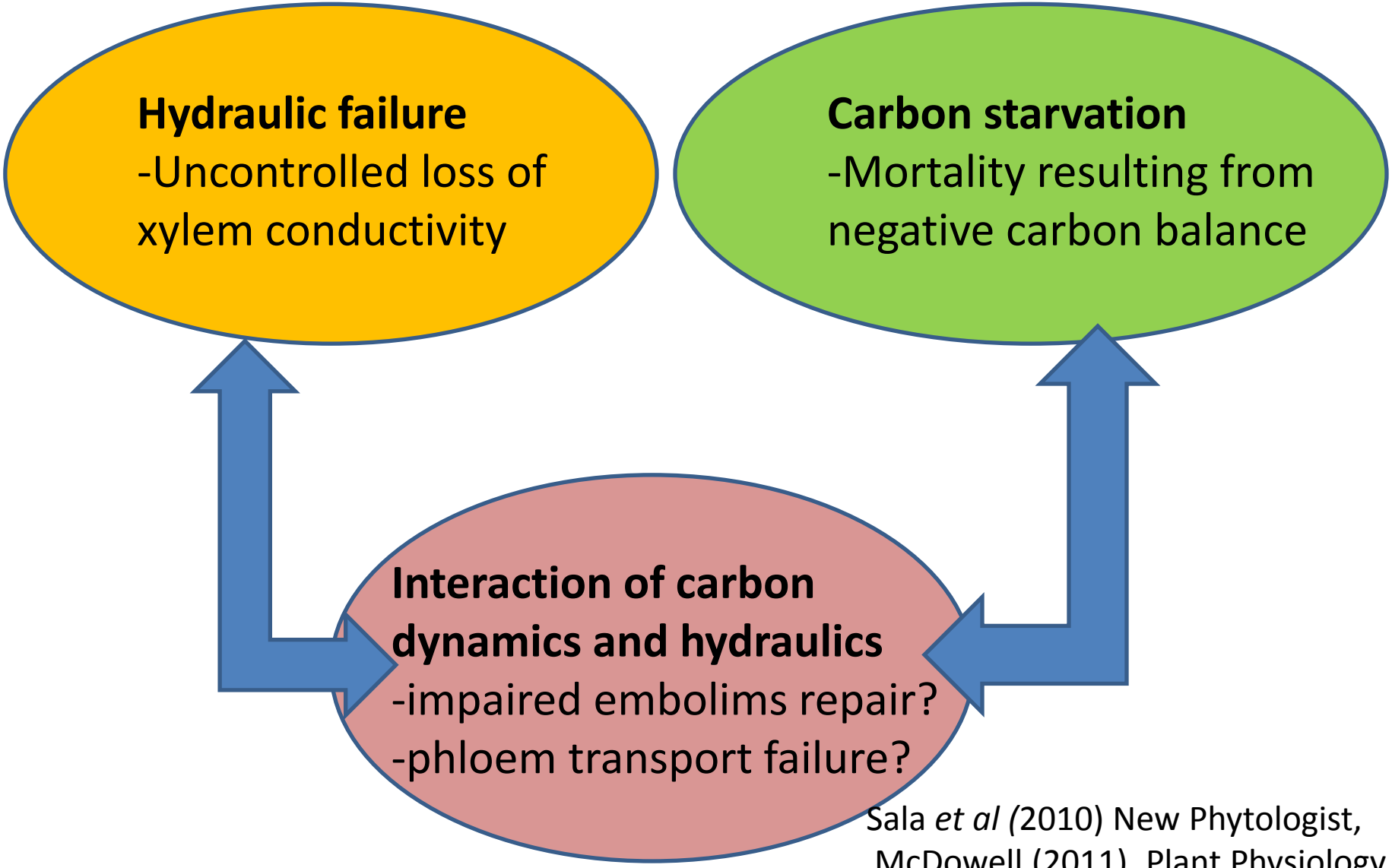
Sanna Sevanto, Nate McDowell, L. Turin Dickman, Robert Pangle, William T. Pockman

Los Alamos National Laboratory

University of New Mexico

# **Motivation:** How do trees die during drought?

McDowell *et al* (2008) New Phytologist




Sala *et al* (2010) New Phytologist,
McDowell (2011), Plant Physiology

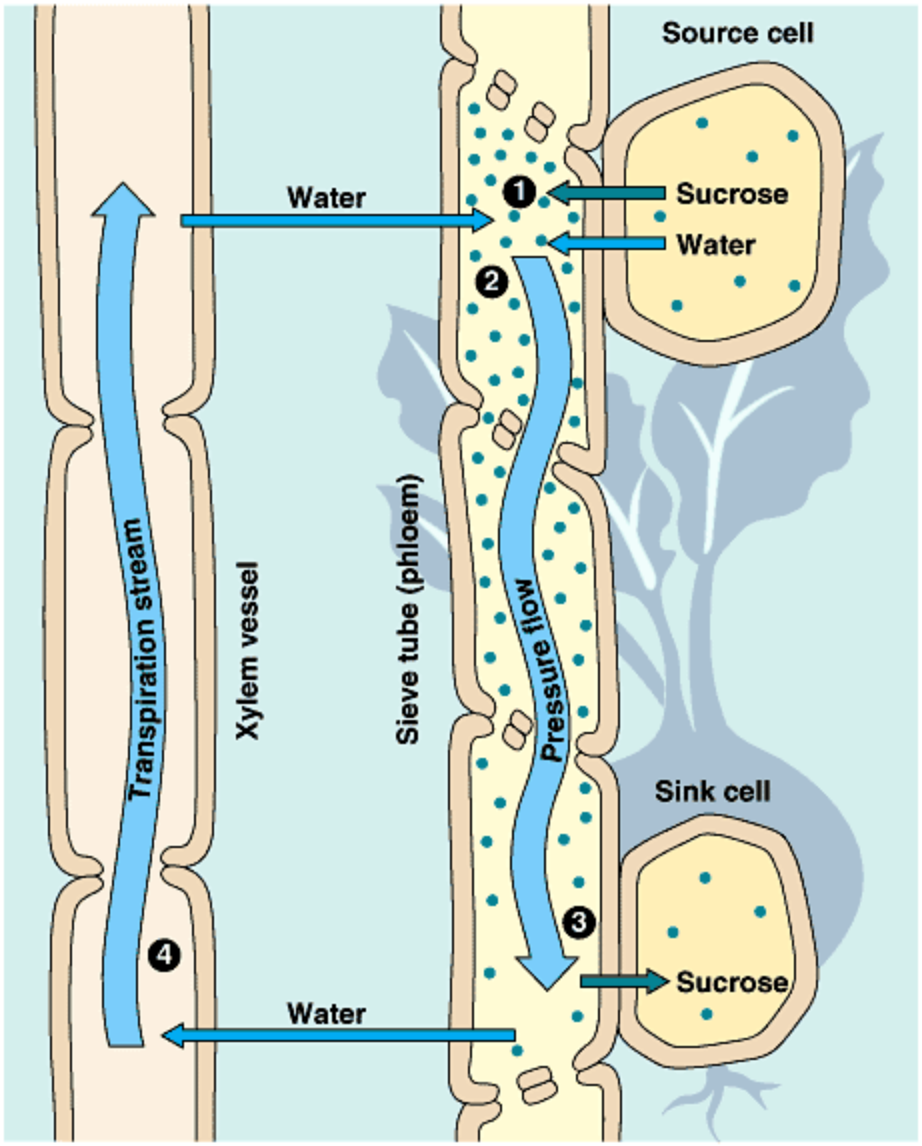
# Questions:

- How does drought affect phloem transport?

- What kind of a phloem could operate during drought?

- Does phloem failure occur during drought, and if so is it important for survival?

# Classical view of phloem transport:





**Semipermeable source** connected to a **semipermeable sink** via a **non-permeable tube**

Volume flow rate:

$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$

Munch, 1928; Thornley & Johnson 1990; Minchin *et al* 1993

Increasing viscosity may lead to…

**Blockage of axial transport**

Holtta, Mencuccini & Nikinmaa 2009

# What kind of a phloem could operate during drought: Classical view

$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$

The larger the conduits, the higher the flux, even with high viscosity

If we assume independent sieve elements

$$Q_{tot} = \sum_{i=1}^{n} q_i = \sum_{i=1}^{n} \frac{\pi r_i^4}{8L\eta_i} RT(c_{source} - c_{sink})_i = nq$$

More conduits = higher flux

# Any support for this theory?

**Pinon pine:**

-closes stomata normally at -2.3 - -2.5 MPa

-Average Ap/Ax = 0.82

**Juniper:**

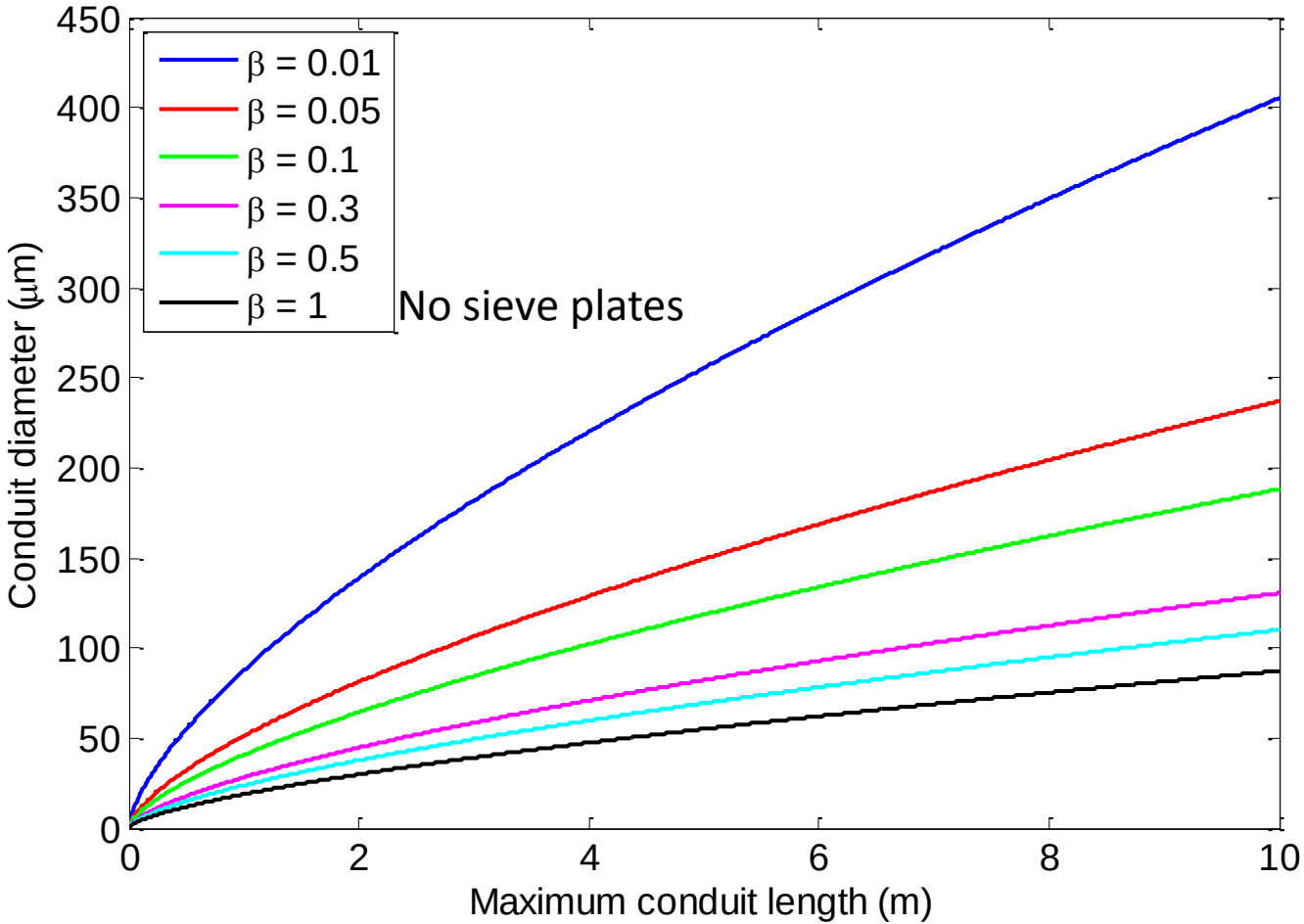
-closes stomata at -6 - -7MPa

-Average Ap/Ax = 1.16

# Is there a viscosity limit?

$$R = 2L L_p \frac{8\eta L}{\beta r^3} = \frac{Axial\ resistance}{Radial\ resistance}$$

Thompson & Holbrook 2003 PCE

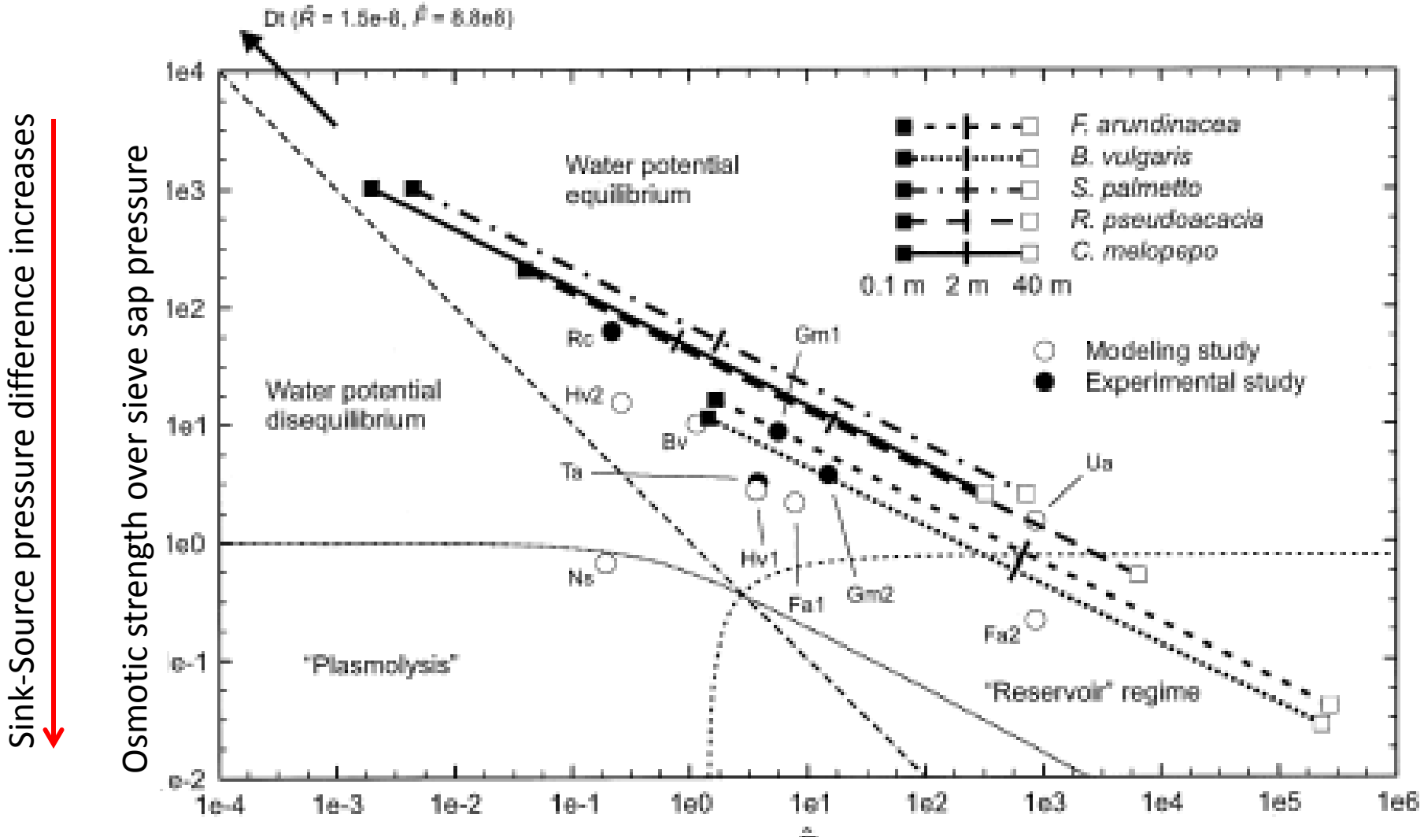


# Does phloem transport cease during drought?

$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$

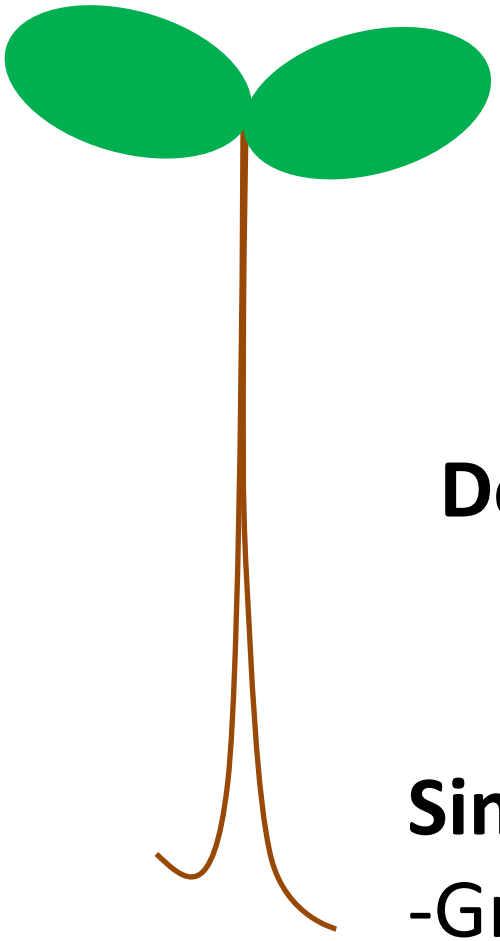
Plants can compensate for increasing resistance by increasing source –sink pressure difference

# Does phloem transport cease during drought?




Thompson & Holbrook (2003), PCE

# Does this matter at all?



**Source:**

-Stomatal closure ⟹ reduced productivity

**Do we need transport?**

**Sink:**

-Growth ceases

-Respiration decreases (or not?)

# What have we observed? Experiment with pinon pine

Drought treatment:

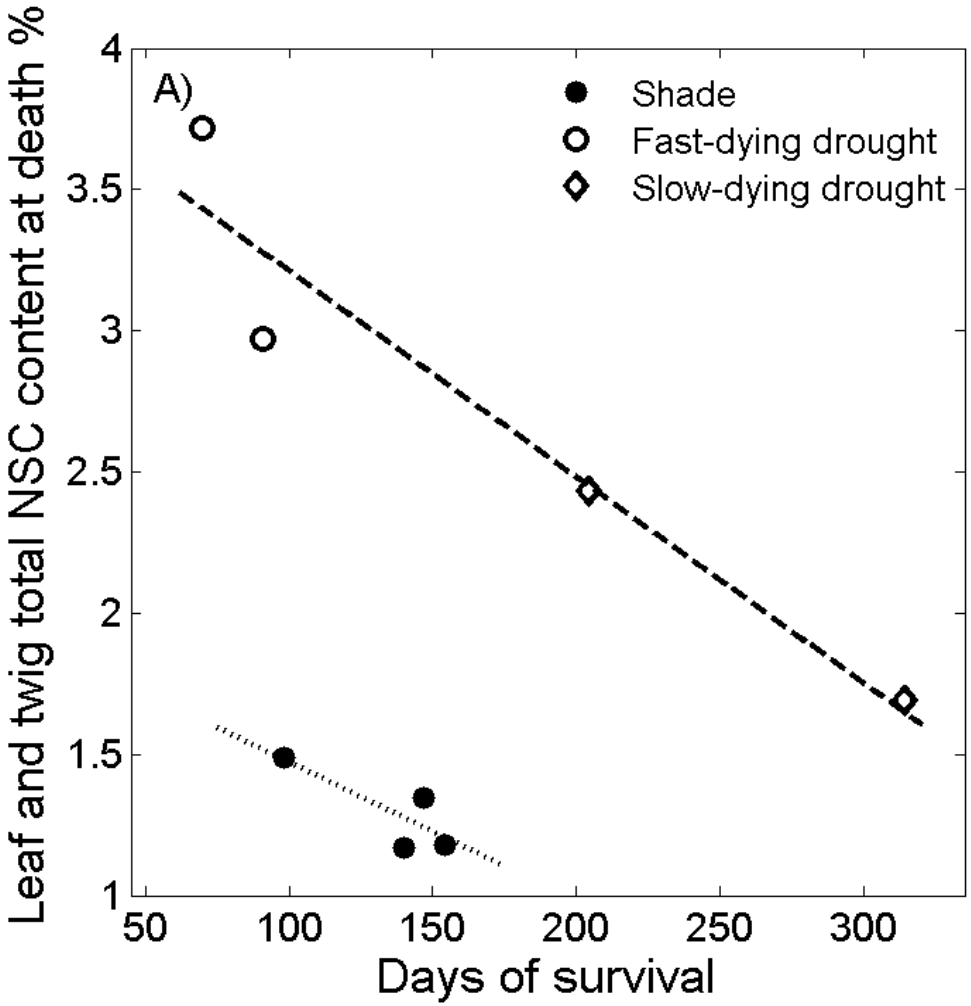
-fast dying trees

-slow-dying trees

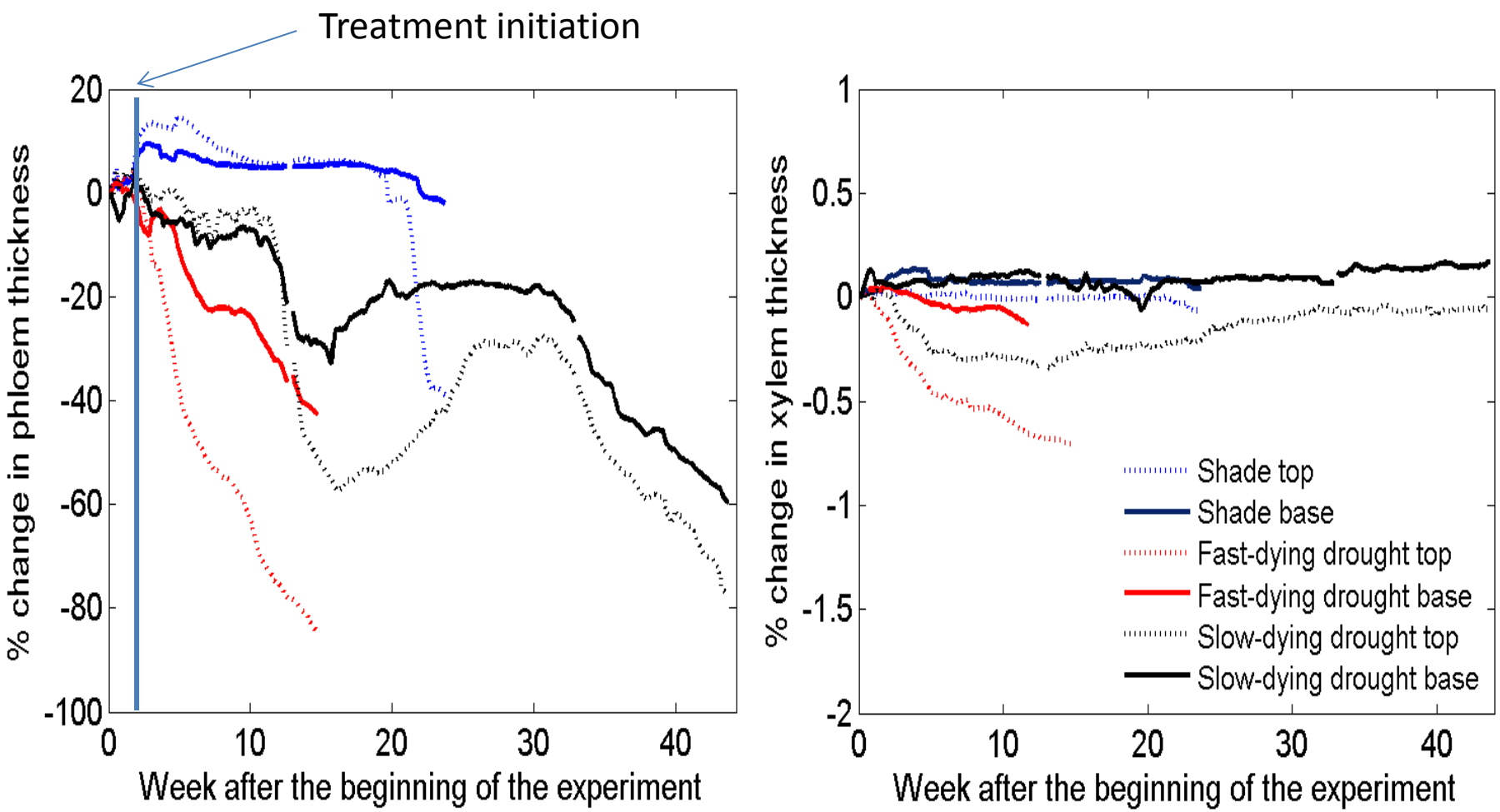
Shade treatment

Sevanto *et al*. (2013) PCE

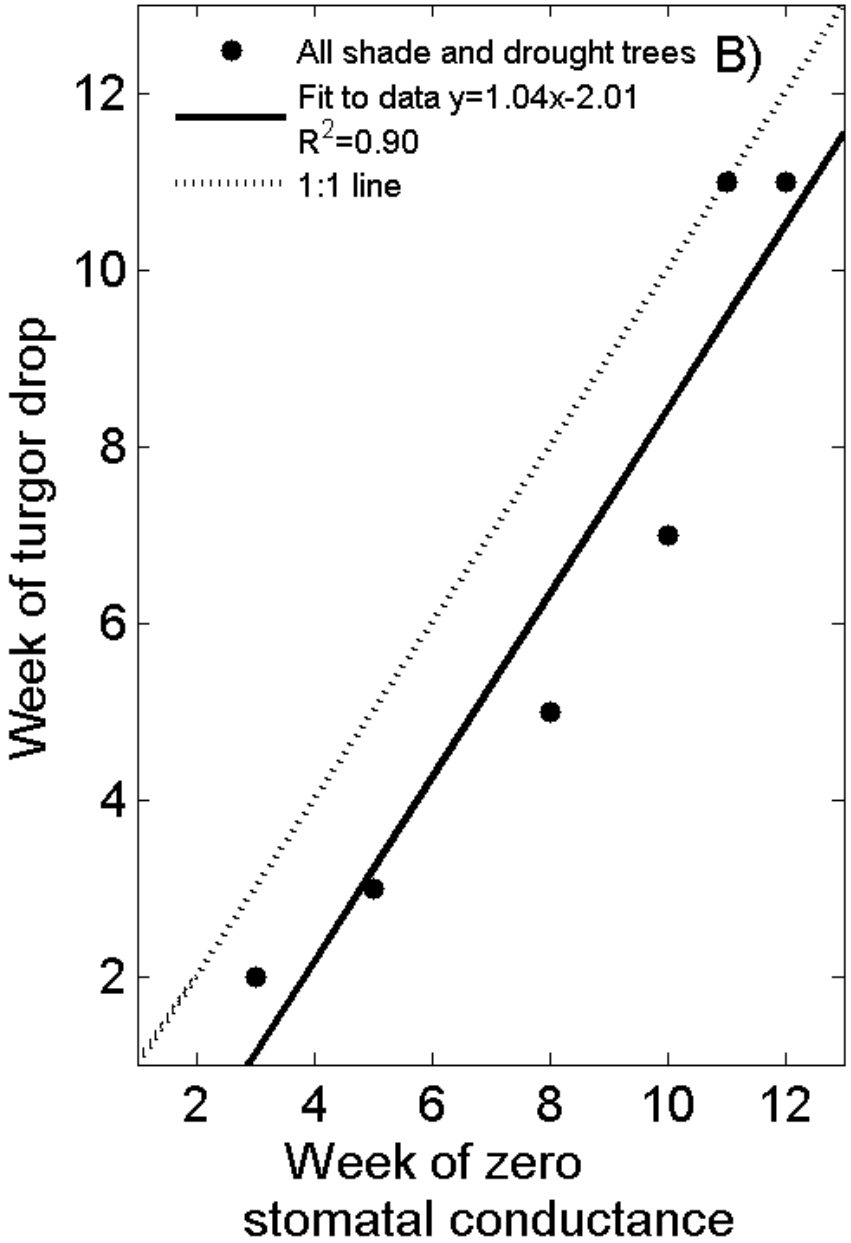
# Access to carbohydrate stores affects survival time



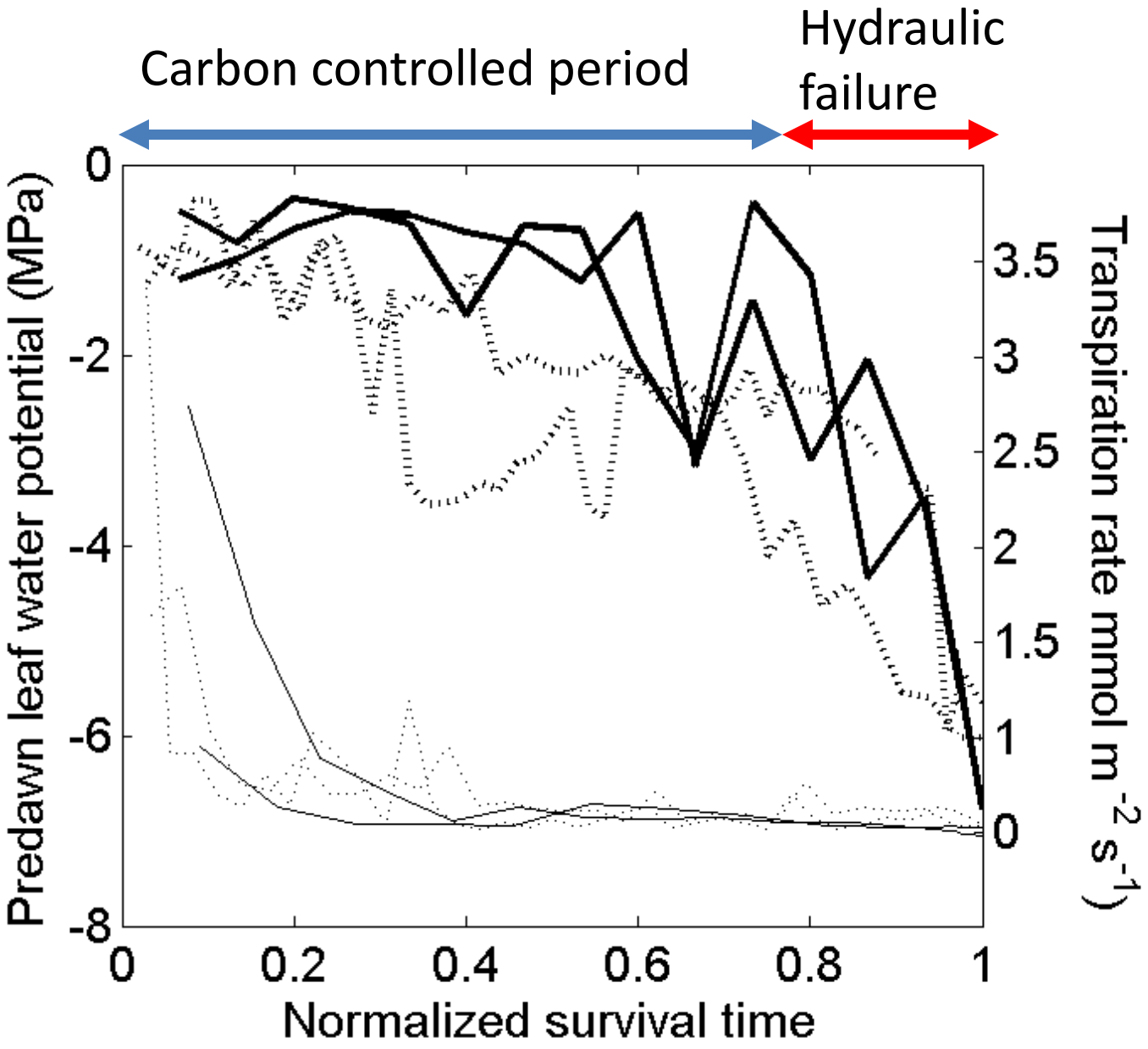
# Phloem turgor collapses during drought



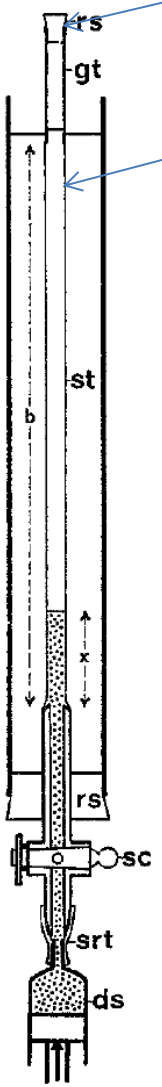
# Turgor collapse precedes stomatal closure



# Phloem turgor collapse determines survival time



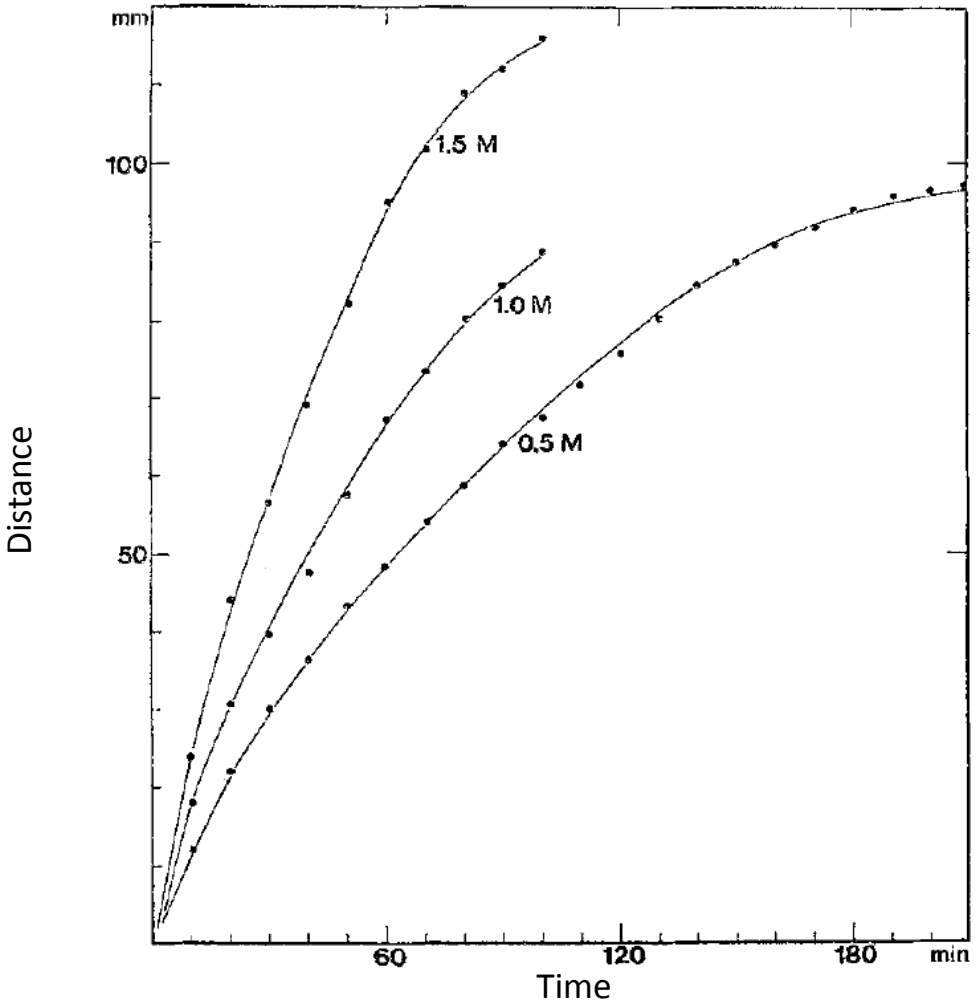
# Semipermeability of the walls Eschrich *et al.* (1972) Planta 107:279-300



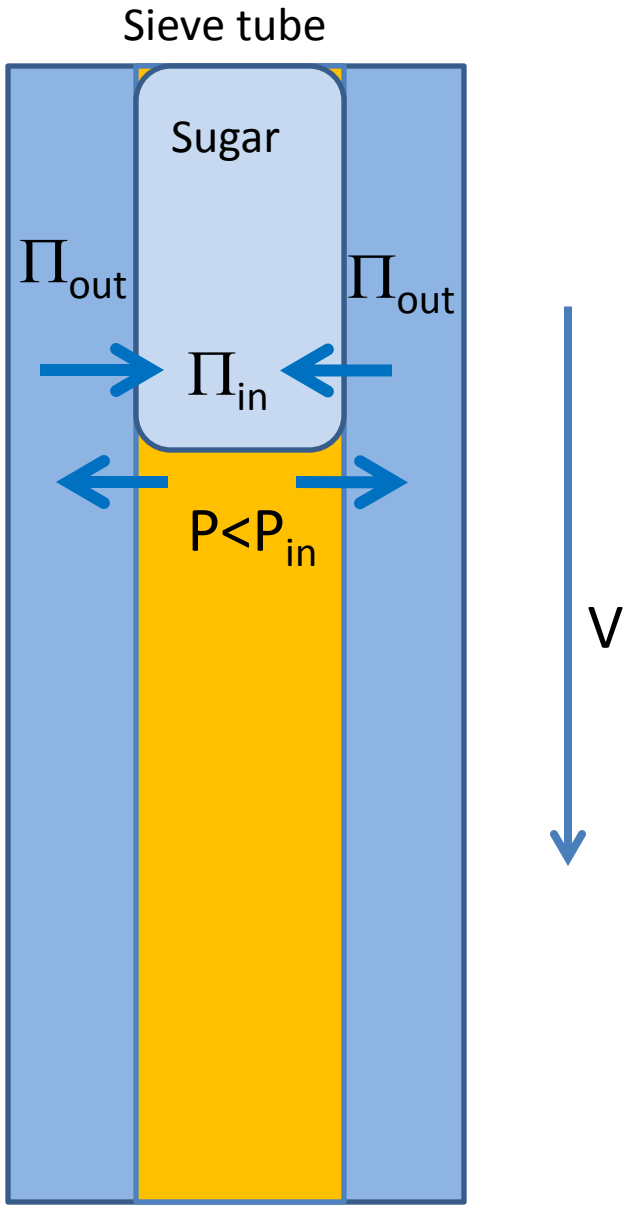

Rubber stopper

Dialysis tube

With rubber stopper



# How does this work? Eschrich *et al.* (1972) Planta 107:279-300




$$V \propto \Pi_{out} - \Pi_{in}$$

In the classical models:

$$V \propto \frac{\partial P}{\partial z}$$

See also Knoblauch & Peters (2010) PCE

# Permeability limits?

Eschrich *et al.* (1972) Planta 107:279-300

Initial transport distance

$$v = (L - z_0)\frac{2\Pi_{eq} L_p}{r} e^{\frac{2L_p \Pi_{eq}}{r}}$$

$L_p$ goes to zero, v goes to zero

**Note also that v increases with decreasing r**

# Conclusions:

**How does drought affect phloem transport?**

-Drought leads to phloem dysfunction, BUT the mechanism may be different than we thought

**What kind of a phloem could operate during drought?**

-It depends on what we believe about the transport mechanism. Semipermeability might be a key.

-Timing of phloem turgor collapse affects plant survival time